



JS Army Corps  
of Engineers  
North Central Division

# GREAT LAKES LEVELS

Update Letter No. 85 August 3, 1992

## Great Lakes Flow Measurements (Last of 2-Part Series)

Last month we provided an article on the Great Lakes flow measurements of the St. Marys, St. Clair, Detroit, Niagara, and St. Lawrence Rivers. These measurements are conducted jointly by the U.S. Army Corps of Engineers, Detroit District, and

Environment Canada, Water Survey of Canada, Ontario Region. In the article, we discussed the need for accurate flow measurements, and methods and standards used in the flow metering and measurement sites. This month's

article is a continuation of the same topic.

### Site Selection

The selection of a measuring site begins with the acquisition and study of all available maps,

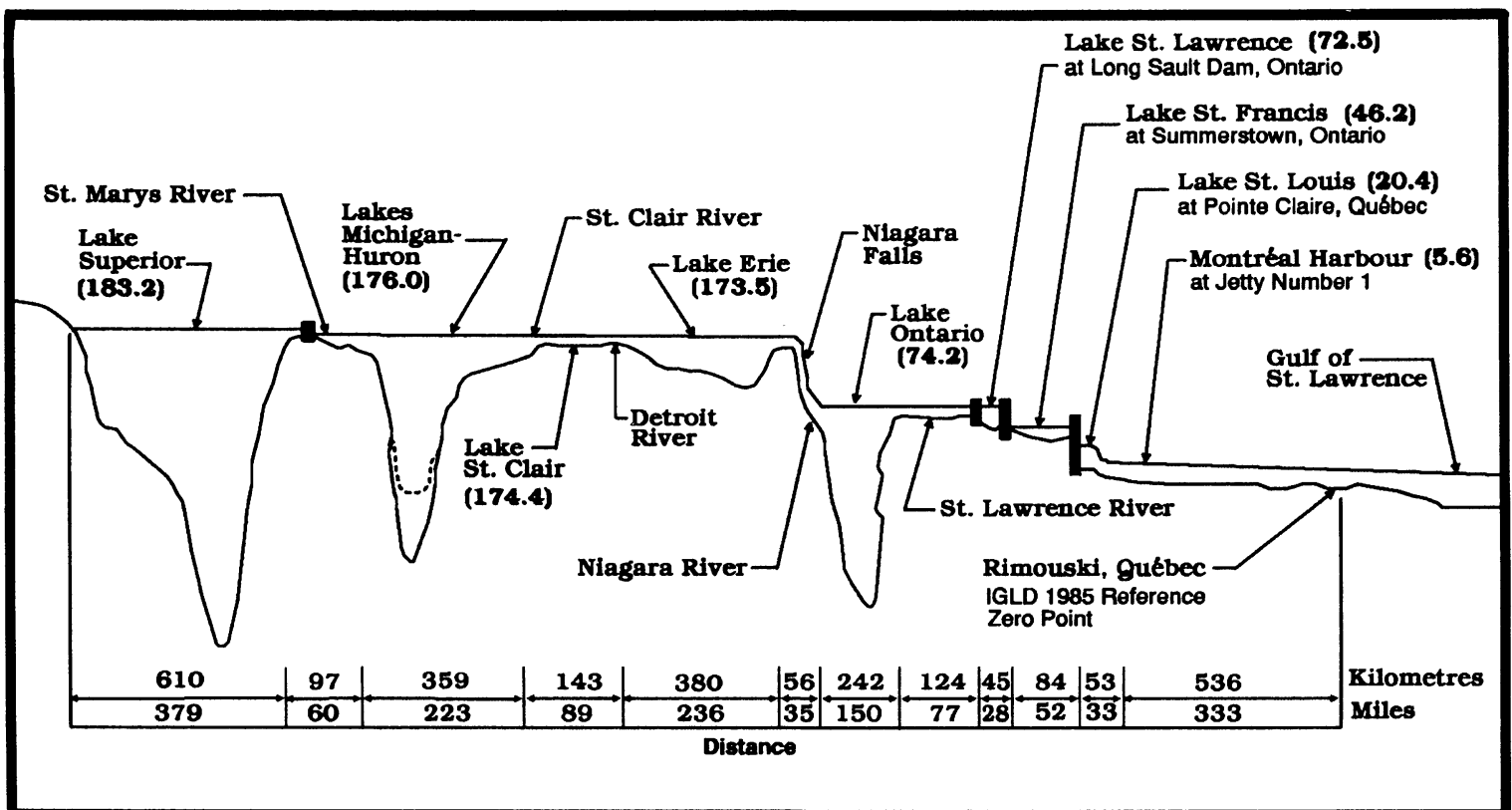


Figure 1. Profile of the Great Lakes - St. Lawrence River

hydrographic charts, aerial photographs, notes and records from previous surveys in the area.

The preferred metering site in the river to be measured is usually located as close as possible to its lake outlet, water level gage, or hydraulic structure in order to minimize uncertainties due to time lags, intervening storage areas, local inflows, or other such complications.

Operational considerations take into account: safety and accessibility; site suitability to available equipment and proposed measurement procedures, particularly with respect to anchoring, placement of buoys, and establishment of vertical and horizontal control; and, compatibility with other users of the channel, including navigation, pleasure boating, fishing, and water skiing.

After a site has been selected, the task of laying out the measuring section begins. This usually requires establishing vertical and horizontal controls and cross-sectioning the reach at suitable intervals using echo sounding equipment.

### Vertical Control

Vertical control requires the establishment or recovery of existing bench marks, reference points, and water level gages so that measurements can be tied into an established Great Lakes vertical grid, or datum. Beginning on January 1, 1960, International Great Lakes Datum 1955 (IGLD 1955), was the standard datum on the Great Lakes - St. Lawrence River system (Figure 1). Prior to that date, U.S. Lake Survey Datum 1903 and 1935 were the stand-

ards. Commencing January 1, 1992, a new datum (IGLD 1985) was introduced (See Update Article No. 76).

After recovering or establishing bench marks and secondary reference points at the site, a gage for measuring the water level at the section is set up and tied into the vertical control network. If a permanent water level gage is close enough, this latter step is unnecessary.

### Horizontal Control

Horizontal control is the term applied to define the horizontal positions of all points occupied during the measurement series. This allows these landside reference points to be located on maps and charts. Generally, small monuments are permanently installed at the control points and they are referenced to facilitate future recovery. Until the early 1970s, triangulation was the customary method of horizontal control for boat measurements on the main outlet channels.

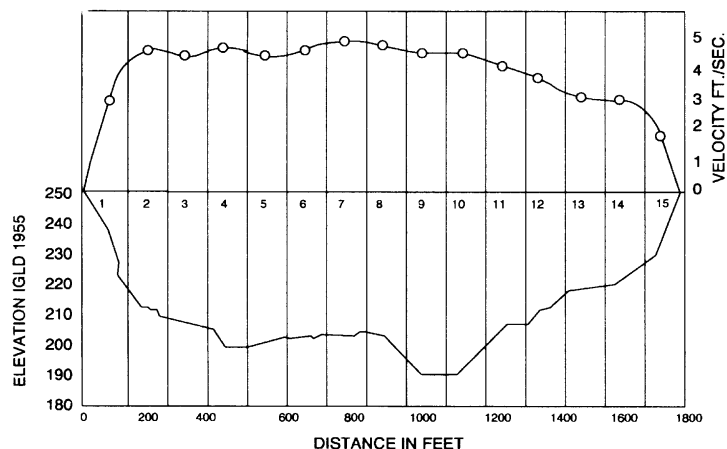
In the mid-1970s, triangulation methods were replaced by electronic distance instruments

for positioning survey craft during measurements. Often, the former control points were maintained as backup in case of malfunction of the electronic distance instrument.

### Sounding

After establishment of both vertical and horizontal control points and the installation of a section gage, the next step in a discharge measurement program is the accurate definition of the bottom profile of the measuring section. Prior to echo sounders coming into general use in the mid-1950s, lead line soundings were the usual method of defining the bottom contour.

The sounding craft (measuring depth of water) traverses the channel along the section line, its position on the line determined by sighting, using an on-board sextant or shore operated theodolite. With recent technology, a digital distance measuring unit is interfaced with the sounder and event lines are automatically marked on the bottom profile chart at preselected distance intervals.



**Figure 2. Transverse Velocity Profile**

The water level at the section gage is read at the beginning and completion of each section sounding traverse and entered on the notes or charts. Since water levels can change rapidly, a reference water level is selected and all soundings adjusted to this water level prior to being plotted.

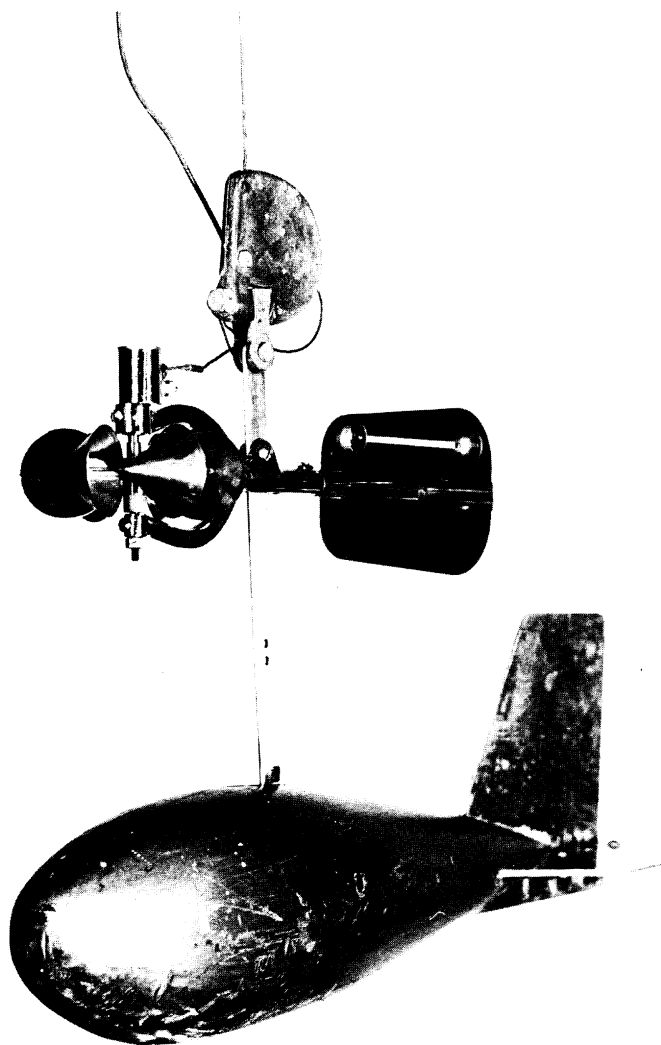
### Panel Selection

Since stream velocities vary both in the vertical (depth of water) and in the horizontal (width of the river), it is necessary to divide the measuring section into workable segments or panels. As such, the next step is the determination of the panel boundaries. Panel selection is designed to optimize velocity sampling in the section and is determined by measuring and plotting mean vertical velocities at selected points along the measurement section. Connecting these points results in a transverse velocity curve, which shows the distribution of these mean vertical velocities. Figure 2 shows an example of a transverse velocity curve.

The transverse discharge curve or profile is then drawn through the series of plotted points representing the products of the corresponding values of depth and mean vertical velocity across the section. The area under the curve, which represents the total discharge, is then divided into the required number of panels such that any one panel does not contain more than ten percent of the total discharge.

### Measurement Procedure

The usual procedure is to anchor the boat during the



**Figure 3. Price Current Meter**

measurements, along the section line, using either a number of buoys anchored above the section, or anchoring the boat to the river bottom itself. This procedure is followed for each panel to be measured. It is essential to maintain the boat as stationary as possible while metering.

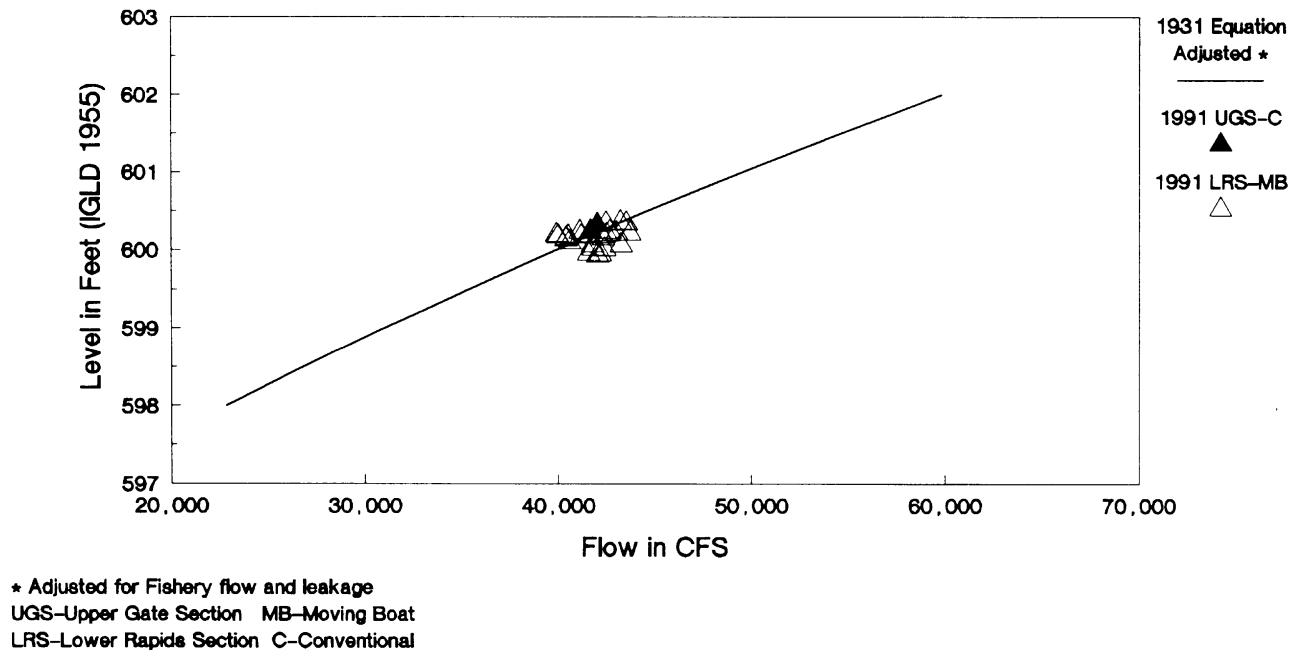
The first mechanical current meters used by the U.S. Lake Survey on the outlet channels were equipped with both cup and propeller type rotors. They operate on the principle that the rotor speed is proportional to current speed. The Price cup-

type current meter was first used on the outlet channels in 1909. In 1953, it became the standard meter for use in the outlet channels. However, the Ott meter, which is a propeller type, has been adopted as the standard meter for moving-boat measurements because it is less affected by oblique currents. Other makes of meters currently in use include the Marsh-McBirney, an electromagnetic flow and current direction meter, and the acoustic doppler current profilers, which use the principle of sound transmission and acoustic doppler shift.

## St. Marys River Flow Measurements

Fourteen Gates Open (#2-15)

$$Q=2458(SWP-593.65)^{**1.5}$$



**Figure 4. Stage-discharge Relationship**

Meters are rated before and after each measurement program at the naval tank rating stations at the University of Michigan in Ann Arbor, Michigan, and at the National Calibration Service of the National Water Research Institute (NWRI), in Burlington, Ontario. This is accomplished by attaching meters to a motorized platform which moves through still water at varying defined speeds.

The most frequently used meter-weight combination on the outlet channels is the Price meter mounted on a steel bar above a 100-pound Columbus style lead stabilizing weight, as shown in Figure 3. The meter and weight combination is suspended by special galvanized steel cable, with an insulated core conductor for transmitting electrical impulses

from the meter to the counter. Meter propeller or cup revolutions are transmitted as electrical impulses to electromagnetic counters through a system of cables and relays. These revolution impulses are produced by closing a low voltage electrical circuit by a wire contact or magnetic reed switch in the meter head. The revolutions are usually counted for time periods ranging from one to five minutes, with two minutes being the most commonly used. Meter counts are recorded on standard data sheets along with the time, date, and other relevant available data such as water levels and climatic conditions.

All these efforts ultimately determine a total discharge at the measurement section. As

previously mentioned, panel areas are computed from measured widths and depths for each panel. Mean panel velocity is the area under the transverse velocity curve between the panel boundaries, divided by the panel width. The mean panel velocities are then multiplied by the corresponding panel areas to obtain the panel discharges, which are then summed across the section to obtain the measured stream discharge.

### Theoretical Discharge Determination

Periodic discharge measurements in the Great Lakes outlet channels are used to calibrate other models for determining discharge, including stage-

discharge equations and unsteady flow numerical models.

Stage-discharge equations provide a relationship between the water surface elevation at a particular reach of the river and its corresponding discharge. This correlation is obtained from numerous field measurements over a range of lake levels, and the equations are developed using one or two water level gages. Once the equations are determined, a discharge can be calculated at any time based upon the prevailing water levels for the reach. A typical stage-discharge relationship is shown in Figure 4.

Several numeric unsteady flow models have also been developed for the connecting channels. These models rely on the simultaneous solution of

equations to determine discharge and stage at specified points along the channels. Field measurements are used to create and calibrate these models. Because of the dynamic nature of the outflow rivers of the Great Lakes, periodic measurements are required to maintain the veracity of the derived equations. Real-time data from water level gages are used in the models to simulate the flows at the present time.

The amount of water flowing in a river can be determined by periodic field measurements, as described above, or through the use of equations and models which are based on field measurements. Monthly outlet channel flows are computed and published for general information

and for study purposes. Table 1 depicts the monthly averages and extremes for the Great Lakes outlet channels based on the period 1900-1989. Discharge data are important for many purposes and the field collection and theoretical determinations are fascinating engineering accomplishments.



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**Table 1**  
**Great Lakes Outlet Channels**  
**Monthly Flows**  
**(Cubic Feet Per Second)**

<u>Great Lakes Outlet Channel</u>	<u>Average</u>	<u>Maximum</u>	<u>Minimum</u>
St. Marys River	76,000	132,000	41,000
St. Clair River	183,000	238,000	106,000
Detroit River	187,000	250,000	112,000
Niagara River	202,000	268,000	116,000
St. Lawrence River	242,000	350,000	154,000

**Note: Based on the period 1900-1989.**

# Great Lakes Basin Hydrology

The precipitation, water supplies, and outflows for the lakes are provided in Table 2. Precipitation data include the provisional values for the past month and the year-to-date and long-term averages. The provisional and long-term average water supplies and outflows are also shown.

**Table 2**  
**Great Lakes Hydrology<sup>1</sup>**

PRECIPITATION								
BASIN	JULY				YEAR-TO-DATE			
	1992 <sup>*</sup>	AVG. <sup>**</sup>	DIFF.	% OF AVG.	1992 <sup>*</sup>	AVG. <sup>**</sup>	DIFF.	% OF AVG.
Superior	3.8	3.2	0.6	119	16.0	16.3	-0.3	98
Michigan-Huron	4.0	3.0	1.0	133	16.2	17.6	-1.4	92
Erie	7.4	3.3	4.1	224	22.9	20.4	2.5	112
Ontario	5.2	3.1	2.1	168	21.7	19.8	1.9	110
Great Lakes	4.5	3.1	1.4	145	17.7	17.9	-0.2	99

LAKE	JUNE WATER SUPPLIES <sup>***</sup>		JUNE OUTFLOW <sup>3</sup>	
	1992 <sup>2</sup>	AVG. <sup>4</sup>	1992 <sup>2</sup>	AVG. <sup>4</sup>
Superior	167,000	130,000	74,000	81,000
Michigan-Huron	161,000	127,000	184,000 <sup>5</sup>	195,000
Erie	64,000	4,000	215,000 <sup>5</sup>	211,000
Ontario	51,000	24,000	260,000	259,000

<sup>\*</sup>Estimated (inches)

<sup>\*\*</sup>1900-90 Average (inches)

<sup>\*\*\*</sup>Negative water supply denotes evaporation from lake exceeded runoff from local basin.

<sup>1</sup>Values (excluding averages) are based on preliminary computations.

<sup>2</sup>Cubic Feet Per Second (cfs)

<sup>3</sup>Does not include diversions

<sup>4</sup>1900-89 Average (cfs)

<sup>5</sup>Reflects effects of ice/weed retardation in the connecting channels.

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